Extended-MHD modeling of Wide Pedestal and standard Quiescent H-mode DIII-D plasmas using the NIMROD code

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To extrapolate standard Quiescent H (QH)- [1, 2] and Wide Pedestal QH (WPQH)-mode [3, 4] regimes to future fusion devices, we need to clarify both the interaction mechanisms between impurity species and bulk plasma on these Edge Localized Mode (ELM)-free regimes (given that, operationally, these modes have large impurity concentration [5]), and distinguish the regimes from the perspective of magnetohydrodynamics (MHD). Our full extended-MHD (xMHD) linear simulations using NIMROD [6] show the crucial role of multispecies collisional and xMHD effects on the WPQH-mode MHD stability with large impurity content [7]. While transforming carbon to tungsten has a minimal impact on the pedestal stability, a pure deuterium plasma is more unstable and thus may be more prone to ELMing behavior. We show here nonlinear xMHD simulations that compare the dynamics of WPQH and standard QH-mode DIII-D plasmas. The WPQH-mode simulation shows low-n ($n \sim 1-5$) modes, as observed experimentally [8], and also exhibits turbulence localized at intermediate-n ($n \sim 20$) that we hypothesize is associated with electron-mediated modes [9]. In contrast, the standard QH simulation is mostly characterized by low-n modes. Our research highlights that xMHD effects that decouple electron and ion dynamics are essential to model plasmas where coherent and turbulent modes coexist. Work supported by US DOE under grants DE-SC0024592, DE-FC02-04ER54698 and DE-AC02-09CH11466.

References

[1] K.H. Burrell *et al.*, Phys. Plasmas **8**, 2153 (2001).
[2] K.H. Burrell *et al.*, Phys. Plasmas **12**, 056121 (2005).
[3] X. Chen *et al.*, Nucl. Fusion **57**, 022007 (2017).
[4] K.H. Burrell *et al.*, Nucl. Fusion **60**, 086005 (2020).
[5] C. Paz-Soldan *et al.*, Plasma Phys. Control. Fusion **63**, 083001 (2021).
[6] C.R. Sovinec *et al.*, J. Comput. Phys. **195**, 355 (2004).
[7] J.J. Dominguez-Palacios Duran *et al.*, Nucl. Fusion **66**, 036033 (2026).
[8] G. Yu *et al.*, Plasma Phys. Control. Fusion **64**, 095014 (2022).
[9] Z. Li *et al.*, Nat. Commun. **16**, 11526 (2025).